Date: 21/10/2021

Q1. Sketch the wavefronts corresponding to converging rays.

Q2. Name the shape of a wavefront originating from (a) a point source (b) a line source.

Q3. Differentiate between a ray and a wavefront?

O4. What is a wavefront?

Q5. Ray optics is based on the assumption that light travels in a straight line. Diffraction effects (observed when light propagates through small apertures/slits or around small obstacles) disprove this assumption. Yet the ray optics assumption is so commonly used in understanding location and several other properties of images in optical instruments. What is the justification?

Q6. Two students are separated by a 7 m partition wall in a room 10 m high. If both light and sound waves can bend around obstacles, how is it that the students are unable to see each other even though they can converse easily.

Q7. When a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the centre of the shadow of the obstacle. Explain why?

Q8. In what way is diffraction from each slit related to the interference pattern in a double-slit experiment?

Q9. What is the Brewster angle for air to glass transition? (Refractive index of glass = 1.5.)

Q10. What is the geometrical shape of the wavefront of the light diverging from a point source? Sketch the wavefronts corresponding to diverging rays.

Q11. Given one basic difference between diffraction and interference of light.

Q12. How does resolving power of a telescope change on decreasing the aperture of its object lens? Justify your answer.

Q13. Define resolving power of a telescope.

Q14. For a given single slit, the diffraction pattern is obtained on a fixed screen, first by using red light and then with blue light. In which case, will the central maxima, in the observed diffraction pattern, have a larger angular width?

Q15. State the condition for diffraction of light to occur.

Q16. What is diffraction of light?

Q17. Will ultrasonic waves show any polarisation? Give reasons for your answer.

Q18. What evidence is there that sound is not electromagnetic in nature?

Q19. How is a wavefront to the direction of corresponding rays?

Q20. The 6563 Å H_a line emitted by hydrogen in a star is found to be red shifted by 15 Å. Estimate the speed with which the star is receding from the Earth.

Q21. A slit of width a is illuminated by monochromatic light at normal incidence. Draw the intensity distribution curve observed on the screen due to diffraction.

Q22. Why is diffraction of sound waves easier to observe than diffraction of light waves?

Q23. In Example 10.3, what should the width of each slit be to obtain 10 maxima of the double slit pattern within the central maximum of the single slit pattern?

Q24. In deriving the single slit diffraction pattern, it was stated that the intensity is zero at angles of $n\lambda/a$. Justify this by suitably dividing the slit to bring out the cancellation.

Q25. What two main changes in diffraction pattern of a single slit will you observe, when the monochromatic source of light is replaced by a source of white light?

Q26. In a single slit diffraction experiment, when a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the centre of the shadow of the obstacle. Explain, why.

Q27. In the diffraction of a single slit experiment, the width of the slit is made double the original width. How does this affect the size and intensity of central diffraction band?

Q28. In the diffraction of a single slit experiment, how would the width of and the intensity of central maximum change, if

(a) slit width is halved and

(b) visible light of longer wavelength is used?

Q29. Two convex lenses of same focal length but of aperture D_1 and D_2 ($D_2 < D_1$), are used as the objective lenses in two astronomical telescopes having identical eyepieces. What is the ratio of their resolving powers?

Q30. How does the resolving power of a compound microscope change on

(a) decreasing the wavelength of light used, and

(b) decreasing the diameter of its object lens?

Q31. What is the basic difference between a source of light and source of radiowaves?

Q32. How will the resolving power of a compound microscope be affected, when (a) the frequency of light used to illuminate the object is increased, and (b) the focal length of the objective is increased. Justify your answer in each case.

Q33. Give two differences between fringes formed in single slit diffraction and Young's double slit experiment.

Q34. Define Resolving power of a telescope. How does diffraction limit its resolving power?

Q35. Define (a) resolving power and (b) magnifying power of a telescope.

Q36. Two towers on top of two hills are 40 km apart. The line joining them passes 50 m above a hill halfway between the towers. What is the longest wavelength of radio waves, which can be sent between the towers without appreciable diffraction effects?

Q37. What is the shape of the wavefront in each of the following cases:

(a) Light diverging from a point source.

(b) Light emerging out of a convex lens when a point source is placed at its focus.

(c) The portion of the wavefront of light from a distant star intercepted by the Earth.

Q38. A parallel beam of monochromatic of wavelength 500 nm falls normally on a narrow slit and the resulting diffraction pattern is obtained on a screen 1 m away. It is observed that the first minimum is at a distance of 2.5 mm from the centre of the screen. Find

(a) the width of the slit

(b) the distance of the second maximum from the centre of the screen.

(c) the width of the central maximum.

Q39. In a single slit diffraction pattern, how is the width of central bright maximum changed, when

(a) the slit width is decreased,

(b) the distance between the slit and the screen is increased and

(c) light of smaller wavelength is used. Justify your answer.

Q40. (a) Why do we not encounter diffraction effects of light in everyday observations?

(b) In the observed diffraction pattern due to a single slit, how will the width of central maximum be affected if

(i) the width of the slit is doubled;

(ii) the wavelength of the light used is increased?

Justify your answer in each case.

Q41. Two wavelengths of sodium light 590 nm, 596 nm are used, in turn, to study the diffraction taking place at a single slit of aperture 2×10^{-6} m. The distance between the slit and the screen is 1.5 m. Calculate the separation between the positions of first maximum of the diffraction pattern obtained in the two case.

Q42. (a) A plane wavefront approaches a plane surface separating two media. If medium 'one' is optically denser and medium 'two' is optically rarer, using Huygens' principle, explain and show how a refracted wavefront is constructed.

(b) Hence verify Snell's law.

(c) When a light wave travels from a rarer to a denser medium, the speed decreases. Does it imply reduction in its energy? Explain.

Q43. What is diffraction of light? Draw a graph showing the variation of intensity with angle in a single slit diffraction experiment. Write one feature which distinguishes the observed pattern from the double slit interference pattern.

How would the diffraction pattern of a single slit be affected when:

(a) the width of the slit is decreased?

(b) the monochromatic source of light is replaced by a source of white light?

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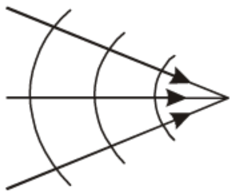
S1.



S2. (a) Spherical wave front (b) Cylindrical wavefront.

S3. **A ray:** An arrow drawn normal to the wavefront and pointing in the direction of propagation of the disturbance is called a ray of light.

A wavefront: A source of light sends out disturbance in all directions in a homogeneous medium, the disturbance reaches all those particles of the medium in phase, which are located at the same distance from the source of light.

S4. A source of light sends out disturbance in all directions in a homogeneous medium, the disturbance reaches all those particles of the medium in phase, which are located at the same distance from the source of light.

The locus of all the particles of the medium, which at any instant are vibrating in the same phase, is called the wavefront.

S5. The justification is that in ordinary optical instruments, the size of the aperture involved is much larger than the wavelength of the light used.

S6. On the one hand, the wavelength of the light waves is too small in comparison to the size of the obstacle. Thus, the diffraction angle will be very small. Hence, the students are unable to see each other. On the other hand, the size of the wall is comparable to the wavelength of the sound waves. Thus, the bending of the waves takes place at a large angle. Hence, the students are able to hear each other.

S7. When a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the centre of the shadow of the obstacle. This is because light waves are diffracted from the edge of the circular obstacle, which interferes constructively at the centre of the shadow. This constructive interference produces a bright spot.

Bending of waves by obstacles by a large angle is possible when the size of the obstacle is comparable to the wavelength of the waves.

S8. The interference pattern in a double-slit experiment is modulated by diffraction from each slit. The pattern is the result of the interference of the diffracted wave from each slit.

S9. Refractive index of glass, $\mu = 1.5$

Brewster angle = θ

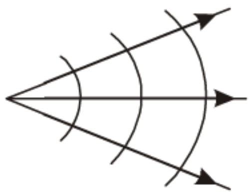
Brewster angle is related to refractive index as:

$$\tan \theta = \mu$$

$$\theta = \tan^{-1}(1.5) = 56.31°$$

Therefore, the Brewster angle for air to glass transition is 56.31°.

S10.



S11. Interference is the result of interaction of light coming from two different wavefronts originating from two coherent sources, whereas diffraction pattern is the result of interaction of light coming from different parts of the same wavefront.

S12. Resolving power of a telescope = $\frac{D}{1.22\,\lambda}$

Therefore, on decreasing aperture (D) of the objective lens, the resolving power of the telescope decreases.

S13. It is defined as the reciprocal of the smallest angular separation between two distant objects, so that they appear just separated, when seen through the telescope.

S14. The angular width of the central maxima,

$$\beta_0 = \frac{2\,D\,\lambda}{a}$$

i.e., $$\beta_0 \propto \lambda$$

Since $\lambda_r > \lambda_b$, the central maximum will have larger angular width for red light.

S15. The size of the obstacle should be of the order of the wavelength used.

S16. The phenomenon of bending of light round the sharp corners and its spreading into the regions of the geometrical shadow is called diffraction.

S17. No it is because, ultrasonic waves are longitudinal in nature.

S18. Because, sound waves can not be polarised.

S19. The wavefront is perpendicular to the direction of rays.

S20. Wavelength of H_a line emitted by hydrogen,

$$\lambda = 6563\ \text{Å}$$

$$= 6563 \times 10^{-10}\ \text{m}.$$

Star's red-shift, $(\lambda' - \lambda) = 15\,\text{Å} = 15 \times 10^{-10}\,\text{m}$

Speed of light, $c = 3 \times 10^{8}\,\text{m/s}$

Let the velocity of the star receding away from the Earth be v.

The red shift is related with velocity as:

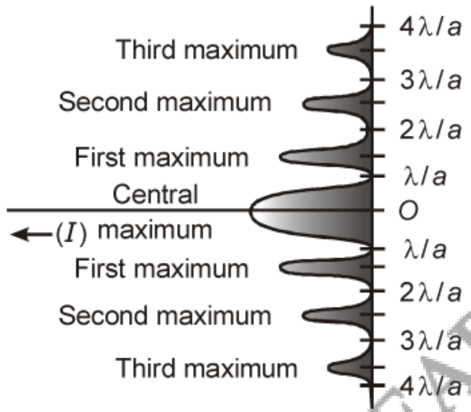
$$\lambda' - \lambda = \frac{v}{c}\lambda$$

$$v = \frac{c}{\lambda} \times (\lambda' - \lambda)$$

$$= \frac{3 \times 10^{8} \times 15 \times 10^{-10}}{6563 \times 10^{-10}} = 6.87 \times 10^{5}\,\text{m/s}$$

Therefore, the speed with which the star is receding away from the Earth is 6.87×10^{5} m/s.

S21.



S22. For diffraction to take place, the size of the obstacle/aperture should be of the order of the wavelength of the waves. Since the wavelength of light ($\approx 10^{-6}$ m) is very small as compared to the size of the obstacle/aperture around us, light cannot be diffracted readily. On the other hand, as wavelength of sound is of the order of such objects, it gets diffracted easily.

S23. We want $a\theta = \lambda, \quad \theta = \dfrac{\lambda}{a}$

$$10\frac{\lambda}{d} = 2\frac{\lambda}{a} \quad a = \frac{d}{5} = 0.2\text{ mm}$$

Notice that the wavelength of light and distance of the screen do not enter in the calculation of a.

S24. Consider that a single slit of width d is divided into n smaller slits.

$\therefore$ Width of each slit, $f' = \dfrac{d}{n}$

Angle of diffraction is given by the relation,

$$\theta = \frac{\frac{d}{d'}\lambda}{d} = \frac{\lambda}{d'}$$

Now, each of these infinitesimally small slit sends zero intensity in direction θ. Hence, the combination of these slits will give zero intensity.

S25. (a) In each diffraction order, the diffracted image of the slit gets dispersed into component colours of white light..

(b) In higher order spectra, the dispersion is more and it results in overlapping of different colours.

S26. The bright spot seen at the centre of the shadow of the obstacle is due to constructive interference of light waves diffracted from the edge of the circular obstacle.

S27. It follows that the size (width) of central maximum band will become ***one half***.

It follows that the intensity of central maximum band will become ***four times***.

S28. (a) The intensity of central maximum will become one fourth.

(b) The intensity of central maximum will decrease.

S29. The resolving power of a telescope ,

$$\text{R.P.} = \frac{D}{1.22\,\lambda}$$

$$\therefore \qquad \frac{(\text{R.P.})_1}{(\text{R.P.})_2} = \frac{D_1}{1.22\,\lambda} \times \frac{1.22\,\lambda}{D_2} = \frac{\boldsymbol{D_1}}{\boldsymbol{D_2}}$$

The telescope having objective lens of aperture D_1 will be preferred. It is because, such a telescope will have greater resolving power and greater light gathering power.

S30. Resolving power of a microscope

$$= \frac{2\mu \sin\theta}{\lambda}.$$

(a) On decreasing wavelength of light, resolving power will increase.

(b) On decreasing diameter of objective lens, semi-vertical angle θ will decrease and hence resolving power will decrease.

S31. In a source of visible light, the atoms act as oscillators producing oscillations independent of each other. Due to this, oscillations produced are randomly oriented (unpolarised) .

In a radio wave source, the charges oscillate in a plane perpendicular to the direction of propagation of radio waves (polarised).

S32. Resolving power of a microscope

$$= \frac{2\mu \sin\theta}{\lambda} = \frac{2\nu\mu \sin\theta}{c} \qquad (\because\ c = \nu\lambda)$$

(a) When the frequency of light is increased, resolving power will increase.

(b) When the focal length of objective is increased, distance between object and objective will increase. It will lead to a decrease in the value of angle θ and hence resolving power will decrease.

S33. (a) In Young's experiment, all the bright fringes formed are of the same intensity, whereas in single slit diffraction experiment, the bright fringes are of varying intensity.

(b) In Young's experiment, fringes of minimum intensity are perfectly dark, whereas in slit diffraction experiment, fringes of minimum intensity are not perfectly dark.

S34. **Resolving power:** Resolving power of a telescope is defined as the reciprocal of the smallest angular separation between two distant objects, so that they appear just separated, when seen through the telescope.

The smallest separation (linear or angular) between the two point objects at which they appear just separated is called the ***limit of resolution*** of an optical instrument and the reciprocal of the limit of resolution is called its ***resolving power***.

S35. (a) **Resolving power:** Resolving power of a telescope is defined as the reciprocal of the smallest angular separation between two distant objects, so that they appear just separated, when seen through the telescope.

(b) **Magnifying power:** Magnifying power of a telescope is defined as the ratio of the angle subtended at the eye by the image formed at the least distance of distinct vision to the angle subtended at the eye by the object lying at infinity, when seen directly.

S36. Distance between the towers, $d = 40$ km

Height of the line joining the hills, $d = 50$ m.

Thus, the radial spread of the radio waves should not exceed 50 km.

Since the hill is located halfway between the towers, Fresnel's distance can be obtained as:

$$Z_P = 20\text{ km} = 2 \times 10^4\text{ m}$$

Aperture can be taken as: $a = d = 50$ m

Fresnel's distance is given by the relation,

$$Z_P = \frac{a^2}{\lambda}$$

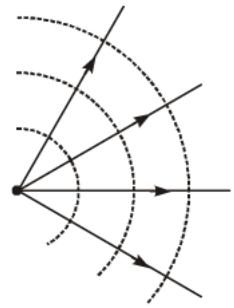
Where, λ = Wavelength of radio waves

$$\therefore \quad \lambda = \frac{a^2}{Z_p}$$

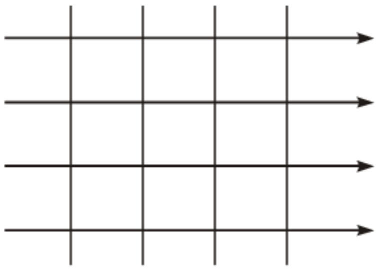
$$= \frac{(50)^2}{2 \times 10^4} = 1250 \times 10^{-4} = 0.1250\text{ m} = 12.5\text{ cm}$$

Therefore, the wavelength of the radio waves is 12.5 cm.

S37. (a) The shape of the wavefront in case of a light diverging from a point source is spherical. The wavefront emanating from a point source is shown in the given figure.



(b) The shape of the wavefront in case of a light emerging out of a convex lens when a point source is placed at its focus is a parallel grid. This is shown in the given figure.



(c) The portion of the wavefront of light from a distant star intercepted by the Earth is a plane.

S38. Given: $\lambda = 500\ \text{nm} = 500 \times 10^{-9}\ \text{m}$; $D = 1\ \text{m}$; $y_1^{\text{min}} = 2.5 \times 10^{-3}\ \text{m}$

(a) We have that

$$y_1^{\text{min}} = \frac{\lambda D}{d} \qquad (\because\ n = 1)$$

Width of the slit, $$d = \frac{\lambda D}{y_1^{\text{min}}}$$

$$= \frac{500 \times 10^{-9} \times 1}{2.5 \times 10^{-3}}$$

$$d = 0.2\ \text{mm}.$$

(b) Distance of the second maximum from the centre of the screen

$$y_2^{\text{max}} = (2 \times 2 + 1)\frac{\lambda D}{2d}$$

$$y_2^{\text{max}} = \frac{5\lambda D}{2d} = \frac{5 \times 500 \times 10^{-9} \times 1}{1 \times 0.2 \times 10^{-3}}$$

$$y_2^{\text{max}} = 0.625\ \text{mm}.$$

(c) Width of the central maximum

$$W = \frac{2\lambda D}{d}$$

$$W = 2 \times y_1^{\min} = 2 \times 2.5 \times 10^{-3}\,\text{m} \qquad \left(\because \quad \frac{\lambda D}{d} = 2.5 \times 10^{-3}\,\text{m}\right)$$

$\therefore$ $$W = 5.0\,\text{mm}.$$

S39. The width of central maximum is given by

$$\beta_0 = \frac{2D\lambda}{a} \qquad \text{... (i)}$$

where the letters have their usual meanings.

(a) **Effect of slit width:** From the equation (i), it follows that $\beta_0 \propto \frac{1}{a}$. Therefore, as the slit width is decreased, the width of the central maximum will ***increase***.

(b) **Effect of distance between slit and screen:** From the equation (i), it follows that $\beta_0 \propto D$. Therefore, as the distance between slit and the screen is increased, the width of the central maximum will also ***increase***.

(c) **Effect of wavelength of light:** From the equation (i), it follows that $\beta_0 \propto \lambda$. Therefore, as the light of smaller wavelength is used, the width of the central maximum will ***decrease***.

S40. (a) For diffraction effects to be observed, the width of the slits should be of the order of wavelength.

(b) Width of central maxima $\beta = \frac{2\lambda D}{d}$.

(i) On doubling the slit width (d), the width of central maxima will become half as $\beta \propto \frac{1}{d}$.

(ii) On increasing the wavelength, the width increases as $\beta \propto \lambda$.

S41. Given: $\alpha = 2 \times 10^{-6}\,\text{m}$; $\lambda = 590 \times 10^{-9}\,\text{m}$; $\lambda' = 596 \times 10^{-9}\,\text{m}$; $D = 1.5\,\text{m}$

Formula: $$Y_{\text{maxi}} = \frac{3\lambda D}{a}; \qquad Y'_{\text{maxi}} = \frac{3\lambda' D}{a}$$

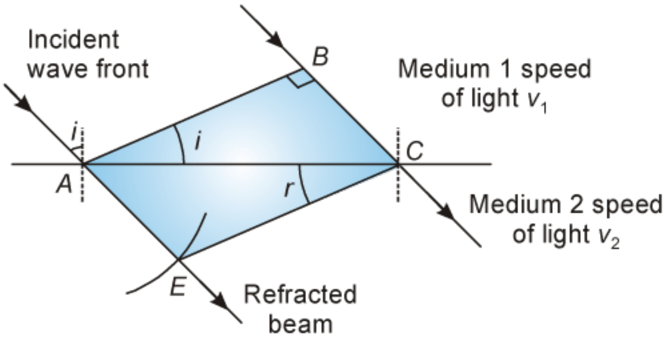
$$\Delta Y = Y'_{\text{maxi}} - Y_{\text{maxi}} = \frac{3D}{a}(\lambda' - \lambda)$$

Calculation: $$\Delta Y = 3 \times 1.5 \times (596 - 590) \times 10^{-9}$$

$$\Delta Y = 13.5 \times 10^{-3}\,\text{m}.$$

S42. (a) As soon as incident wavefront strikes the surface at 'A' a wavefront is generated (Huygen's principle). It begins to travel into the second medium. Refracted wavefront acquires radius. $AE = v_2 t$.

To determine the shape of the refracted wavefront, we draw a sphere of radius $v_2 t$ from the point A in the second medium.



Tangential plane drawn from point C on the sphere gives refracted wavefront.

Here 't' is the time taken by the wave from point 'B' on the incident wavefront to reach the point 'C' on the interface. Distance travelled by the wave is

$$BC = v_1 t$$

(b) From ΔABC $\quad \sin i = \frac{BC}{AC}$ ... (i)

From ΔAEC $\quad \sin r = \frac{AE}{AC}$ ... (ii)

From equations (i) and (ii), we obtain

$$\frac{\sin i}{\sin r} = \frac{BC}{AE} = \frac{v_1}{v_2} \quad \text{... (iii)}$$

We know $\quad n_1 = \frac{c}{v_1}$

and $\quad n_2 = \frac{c}{v_2}$

Substituting in equation (iii), we get

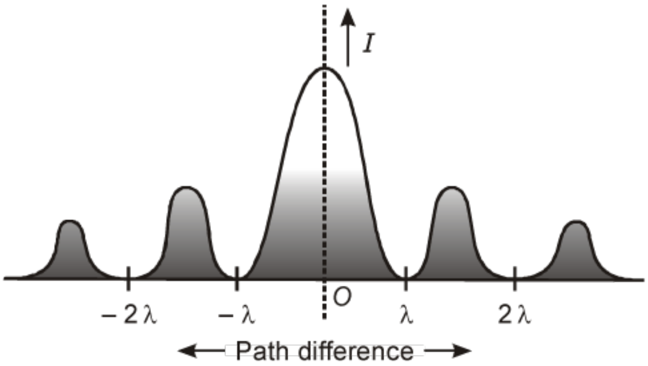
$$n_1 \sin i = n_2 \sin r$$

This is Snell's law of refraction.

(c) No, Energy carried by a wave depends on the amplitude of the wave only.

S43. Diffraction of light: Phenomenon of bending of light round the corners of an obstacles or aperture is called diffraction of light.

Graph showing th variation of intensity with angle in single alit diffraction experiment is



In diffraction pattern, the brightness of successive bright fringes from the centre goes on decreasing whereas in interference pattern all bright fringes are equally bright and have the same width.

$$\text{width of central maxima} = \frac{2\lambda D}{d}$$

(a) When the width of slit (d) is decreased, angular width increases.

(b) When the monochromatic source of light is replaced by source of white light, the diffraction pattern is coloured. The central maxima is bright but other bands are coloured.

Since band width $\propto \lambda$ and $\lambda_{red} > \lambda_{violet}$

So, $\beta_{red} > \beta_{violet}$.